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THE ANATOMY OF *CUTHONA FUTAIRO* N. SP. (=*C. BICOLOR*
OF BABA, 1933) (NUDIBRANCHIA-EOLIDOIDEA)¹⁾

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With Plates V-VI

It is rather puzzling to separate the two genera *Cuthona* ALDER & HANCOCK, 1855 and *Catriona* WINCKWORTH, 1941, satisfactorily from each other. Thus the species *Cuthona bicolor* of BABA, 1933, may belong to the category of *Catriona* (or *Trinchesia* of PRUVOT-FOL, 1951) in its radula teeth having a median cusp not prominently marked off in size from the lateral denticles (see WINCKWORTH, 1941; MACNAE, 1954 a, p. 4; 1954 b, p. 53). Contrary to this expectation, the relative size of the median cusp to the lateral denticles in the radulae has been shown to vary occasionally according to different species in each of the genera *Catriona* and *Cuthona*.

When we take into account the second character concerning the penis stylet which is found in *Catriona* (see MARCUS, E. & E., 1959, p. 917), the author's species may rightly be included within the scope of *Cuthona* by the absence of such a stylet.

During the revisional work on *Cuthona bicolor* of BABA, 1933 (=*Cratena bicolor* of BABA, 1949; *Catriona bicolor* of BABA, 1955) it has been noticed that this is possibly different from *Cuthona?* *bicolor* BERGH, 1904, mainly in the number of the right liver branches before the anus, and in the denticulated figure of the radula teeth (see also BABA, 1961, p. 367, foot-note).

Here a new specific name *Cuthona futairo*²⁾ is established for the animal *Cuthona bicolor* of BABA, 1933, in order to distinguish it from *Cuthona?* *bicolor* BERGH, 1904. This latter is left for further re-identification.

Cuthona futairo BABA, n. sp.

Futairo-minoumiushi

Cuthona bicolor BABA, 1933, pp. 279-280, text-fig. 6.—Tomioka Bay, Amakusa.

1) Contributions from the Mukaishima Marine Biological Station, No. 71.

2) *futairo* means in Japanese 'of two colours'.

Cuthona (Cuthona) bicolor BABA, 1935, pp. 353-354, pl. 7, fig. 5.—Mutsu Bay; BABA, 1937, p. 328 (list only).

Cratena bicolor BABA, 1949, pp. 97-98, 174, pl. 45, fig. 154, text-figs. 123-124.—Sagami Bay.

Catriona bicolor BABA, 1955, p. 56 (generic name change); HAMATANI, 1960, pp. 68-69, text-fig. 8.—Osaka Bay (spawn and veliger).

Cuthonidae. Length 5-20 mm. Rhinophores simple. Foot-corners slightly protruded and angulated. Liver branching and papillae multiplying laterally, but actually the papillae themselves are arranged in a single series on each liver branch and its subdivided twigs. Usually with 6-7 branches in the right liver (and the left-sided partner). Anus acleiproctic, situated in front of the inner corner of the postanal row, nephroproct preanal, genital orifices near the middle of the body-length, lying below the hindmost branch of the right liver. General body-colour pale orange-yellow, deeper towards the tips of the cephalic tentacles and rhinophores, the former with a longitudinal opaque white band on the posterior border. Branchial papillae with an opaque white marking below the tip on the outer surface. Jaw-edge with a row of denticles. Radula ribbon long, the formula $60-90 \times 0.1.0$. Median cusp of the teeth not prominent and slightly retracted, lateral denticles 4-5 on each side. Penis elongated conical, without stylet.

Type specimen: length 10 mm.

Paratype specimens: length 5-20 mm.

Type locality: Mukaishima, Inland Sea of Seto, Japan.

Date of collection: Mar. 12, 1960 and Apr. 2, 1961 (total, 80 specimens).

Occurrence: Mutsu Bay; Sagami Bay; Sugashima near Toba; Osaka Bay; Inland Sea of Seto; Saeki Bay; Amakusa; Toyama Bay.

This species is thus distributed widely on the Pacific side as well as on the Japan Sea side of our country, from north (41° N) to south ($32^{\circ}50' N$). In Osaka Bay it appeared with spawns in great numbers during the years 1951 and 1952, in March, after which it disappeared almost entirely from the shores in this district. In recent years it was found that the species occurs abundantly in the Inland Sea of Seto, crowded on *Sargassum* in shallow water. The natural diet of this species is not known exactly.

Anatomical Details

The main body of the present anatomical study was prepared on the basis of the type-series specimens collected from the vicinity of the Mukaishima Marine Biological Station in the Inland Sea of Seto on April 2, 1961. Some supplementary observation and experiments were made on some other specimens taken from the type locality during March in 1962 and '63.

Externals: Animals of various sizes may be seen in one and the same spawning season. The youngest was 5 mm. The largest and matured ones

attained the total length of 20 mm or more. In many of the specimens, the body including the branchial papillae presents the general colour of pale orange-yellow. This orange-yellow colour is especially so accentuated towards the upper half of the cephalic tentacles and rhinophores that they appear almost orange-red to the tip. Always there is a longitudinal, opaque white band on the posterior border of each of the cephalic tentacles. The branchial papillae themselves are marked each with a crowd of opaque white dots down the tip, on the outer surface. The liver diverticulum within the papillae shines through as a dark green vein. Slight colour variation may occur in different individuals, and this concerns mainly the intensity of the general orange-yellow colour of the body.

The general body-form is as described previously. The rhinophores are simple. The antero-lateral corners of the foot are slightly protruded and angulated, assuming a somewhat unusual aspect in *Cuthona*. The surface of the branchial papillae is quite even.

In the adult specimens there is a thick cluster of papillae specially on the right back-margin, due to the multiplying subdivision of the preanal and post-anal liver branches towards the extreme edge. A somewhat similar case of liver branching is known from *Cuthonella*. Under closer examination, it is found that the branchial papillae are arranged in a single series (not in double or treble series as in *Precuthona*) on each liver branch and its subdivided twigs.

The stomach has usually 6-7 (or 6-10 in BABA, 1949, pp. 97, 174) main branches in the right liver (and the left-sided partner) and 7-9 ones in the left posterior liver on each side. The branchial formula represented by some one specimen (Pl. V, Fig. 3, length 10 mm) is: I (3), II (4), III (6), IV (6-7), V (7), VI (12) : VII (8), VIII (6), IX (5), X (7), XI (6), XII (5), XIII (4), XIV (4), and XV (2-3).

The anus is dorso-lateral. It is acleoprocic (not cleioprocic as in *Precuthona*), being found just in front of the innermost corner of the right postanal liver branch. In *Cuthona? bicolor* BERGH, the anus is said to open in front of the 13th liver branch, and as much as 12 branches are thus expected to constitute the right liver (the total number of liver branches in this species is 22 on each side). The nephroproct is closely in front of the anus.

In this species it is to be noted that the genital orifices are shifted considerably backwardly to near the middle of the body-length, lying actually below the hindmost branch of the right liver. The separated male and female orifices may sometimes occur both in *Cuthona* and *Catriona* (cf. MARCUS, E. & E., 1959, p. 917).

When young (up to 5 mm long), the liver system remains rather simple as in the small species of *Cuthona-Catriona* group. The increasing in total number of the liver branches and the multiplying subdivision of the preanal

and postanal branches take place soon. And these events proceed rapidly with advanced ages, especially on the right margin of the back.

Internals: The internal organization of this species is generally as in *Cuthona* and *Catriona*, but there occurs a greater development in the number of the gonads and in the ramification of the kidney than usual in the latter genera. The pharynx has a pair of slightly branched salivary glands. The oral glands (=ptyaline glands) are in full development, and extend backward to about the middle of the body-length. They are elaborately branched in themselves. Anteriorly, the right and left glands debouch to the oral orifice by a united opening. The gland cells are markedly swollen distally, containing each a large nucleus. Their secretory substance shows no special mucus reaction to toluidine blue. The jaw-edge has as usual a row of denticles (in *Cuthonella* there are several rows of denticles on the jaw-edge). It is to be remarked that the present species agrees with *Cuthona? bicolor* BERGH in that either of these two has a comparatively long radula ribbon (60-90 teeth in *futairo*, 67 in *bicolor*). But the teeth of *bicolor* appear almost pectinate with 7-8 denticles on each side of a short median cusp. In one specimen of *futairo* here dissected for drawing, the jaw-edge had about 20 denticles, and the radula formula was about $60 \times 0.1.0$. The median cusp of the teeth is not prominent and slightly retracted (*Catriona* type); it is approximately as large as the lateral denticles which number 4-5 (5-6 in BABA, 1949, pp. 98, 174) on each side.

The stomach is not a simple sac but has a large blind-sac at its posterior ventral extremity. Similar blind-sac may also be found in other members of *Cuthona-Catriona* group. The whole inner surface of the digestive tract excepting the liver diverticula is lined as usual with a low ciliated epithelium. The intestine has an inner longitudinal ridge.

The liver diverticulum within each of the branchial papillae is a simple (not branched) tube. The proximal junction of the diverticulum with any one of the aforesaid liver branches is guarded by a sphincter muscle. Passing through this junction there is a delicate connective tissue septum marking the detaching line of the papillae. Distally the diverticulum proceeds into the cnidophore sac (cnidosac) with a thick muscular coat. In a natural state the sac is closed at tip as proved by BÜRGIN-WYSS, 1961, in her species. Upon strong mechanical (e.g. pressure) or chemical (e.g. acetic acid) stimuli, the apex of the sac and the dermal epithelium above it break open to form an artificial cnidopore (cf. cnidopore of HERDMAN, 1890, p. 52, and many other authors) through which the cnidocysts containing coelenterate nematocysts stream out freely (see also BÜRGIN-WYSS, 1961, pp. 530-531). In fresh, the cnidocysts comprise colourless homogeneous droplets, but these latter are easily destroyed by a fixing fluid (e.g. acetic acid), and the vacated cytoplasm thus assumes a network appearance.

The nematocysts once taken in the cnidocysts are shown by culture experiments of starved animals to survive for a great length of time (for more than 70 days in the experimentation) without being expelled again from the host-cells, nor being subjected to degeneration (see BÜRGIN-WYSS, 1961, p. 519; cf. GLASER, 1910, pp. 130-131; HENNEGUY, 1925, pp. 427-429). As for the nematocysts free in the lumen of the digestive tract, they are quickly driven out through the intestine and anus within 7-10 days of starvation.

The free edge of the diverticular epithelium is borne upon by fine filaments, gently moving in fresh (see HENNEGUY, 1925, pp. 420-421). This epithelium is entirely glandular (cf. FORREST, 1953, pp. 228-229). The liver cells of the animal taken newly from the sea may superficially be seen acting in two sorts: (1) the yellowish green cells with mostly fine ferment granules, and (2) the colourless ones with coarse ferment granules. But it was very hard to demonstrate certainly these two in the usual histological preparations. No amoeboid movement is observable in the isolated liver cells in the sea-water medium.

The dark green shade of the diverticulum from without seems to be affected in some measure by the opacity of its epithelium which has an immense burden of refringent yellow vacuoles of varying sizes. These latter, in turn, are made up of many fine granules not readily be identified with zooxanthellae (cf. HENNEGUY, 1925, pp. 417-418; NAVILLE, 1926, pp. 283-285; McLAUGHLIN & ZAHL, 1959, pp. 55-70). The granules do not take dyes in mounted sections, and tenaciously keep their refringent yellow colouring there as in fresh material.

The yellow vacuoles thus formed are seen actively shed into the lumen of the diverticulum, sometimes pulled down in that place into fine component granules, and eventually all are conveyed to the exterior as notable elements of the faeces (cf. BÜRGIN-WYSS, 1961, p. 541). During the course of the aforesaid culture experiments, the epithelium of the diverticulum becomes paler (by the disappearance of the yellowish green colouring of the liver cells) and nearly free from the yellow vacuoles ready to discharge.

In this species, however, there are no marked aspects of the vacuole cells or excretory vacuole cells differentiated specially from the general liver epithelium (cf. BÜRGIN-WYSS, 1961, pp. 553-555; HECHT, 1895, pp. 669-671; HENNEGUY, 1925, p. 416).

The kidney in this species is thickly branching, and lies above the left posterior liver. It is entirely colourless. The reno-pericardial canal has a folded wall.

In the haemocoele there are a considerable number of testes each accompanied by several ovaries. The composition of the genital organs is generally as in *Cuthona-Catriona* group, but some mention may be made: The ampulla is sausage-shaped, the spermatheca is spoon-shaped, and the prostata occupies

almost the entire length of the vas deferens. The male and female orifices are separated. The penis, wholly muscular and elongated conical, is devoid of an apical stylet (*Cuthona* type). Attached to the penis and opening into it there is always a vacant pouch formed of a thin (non-glandular) membranous wall. This is tentatively referred to the rudiment of the penis gland. It is said that no penis gland occurs in *Cuthona nana* (see ODHNER, 1939, p. 69; 1944, p. 31).

Compound mucous glands are distributed throughout the ciliated pedal sole; these are especially well-developed towards the lip of the mouth. The general integument of the body is rich in goblet cells.

Summary

- (1) The animal *Cuthona bicolor* of BABA, 1933, is separated from *Cuthona? bicolor* BERGH, 1904, and designated here with a new specific name *futairo*.
- (2) *Cuthona futairo* has the shape of the radula teeth of *Catriona*.
- (3) The species *futairo* is classified in *Cuthona* by the absence of a penis stylet.
- (4) The thickly multiplying subdivision of the liver branches in this species is somewhat exceptional among the members of *Cuthona*. But the internal organization of the said species is fundamentally as in *Cuthona-Catriona* group.
- (5) Some mention is made on the structure and functions of the liver diverticulum and its derivative, the cnidosac.

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EXPLANATION OF PLATES V-VI

Cuthona futairo. All the figures excepting the Pl. V, Fig. 1 are based on the specimens collected from the vicinity of the Mukaishima Marine Biological Station in the Inland Sea of Seto, on April 2, 1961. Serial sections were prepared in horizontal, transverse and longitudinal planes in order to reconstruct the main organ systems in their situation (BOUIN's fixative; DELAFIELD's haematoxylin eosin stain). Part of the body was also dissected in living as well as in preserved specimens.

PLATE V

- Fig. 1. Entire animal in life (Mukaishima, Mar. 12, 1960, length 15 mm). a. anus.
- Fig. 2. A branchial papilla in fresh, showing an opaque white marking down the tip on the outer surface.
- Fig. 3. Naked animal (length 10 mm) from right side to show the arrangement of the branchial papillae. On the right the back margin is somewhat marked off from side by a ridge bearing thick growth of branchial papillae. The subdividing of the preanal and postanal rows proceeds further with the growth of the body. On the left the liver branches remain mostly simple even in the adult stage. a. anus, b. nephroproct, c. male orifice, d. female orifice.
- Fig. 4. Pharynx and the nerve ring from right side ($\times 17$). a. right jaw, b. left jaw. A radula ribbon within.
- Fig. 5. The same from above. a. right jaw, b. left jaw, c. oral tract.
- Fig. 6. The right jaw from outside ($\times 17$).
- Fig. 7. A jaw-edge ($\times 100$).
- Fig. 8. A radula tooth from above ($\times 150$).
- Fig. 9. Digestive system in the body, diagrammatic. a. right liver, b. nephroproct, c. anus, d. branching kidney, e. left posterior liver, f. left anterior liver. The glandular part of the liver system is thickly dotted with black.
- Fig. 10. Stomachal part from above, diagrammatic. a. oesophagus, b. right liver, c. intestine, d. rectum, e. left posterior liver, f. blind-sac of stomach, g. left anterior liver, h. stomach.
- Fig. 11. Cross-section of intestine (a) and of rectum (b).
- Fig. 12. Cross-section of salivary gland ($\times 250$).
- Fig. 13. Part of the oral gland ($\times 50$).
- Fig. 14. Cross-section of the oral gland. Showing a tubule surrounded by gland cells ($\times 150$).
- Fig. 15. Cross-section of the body on level of the pharyngeal bulb ($\times 20$). a. stomach, b. blind-sac of stomach, c. pedal ganglion (below, a buccal ganglion), d. salivary gland, e. pharynx, f. ducts of right and left oral glands, g. jaw-plate, h. oral gland.
- Fig. 16. Cross-section of the odontophore, showing formation of the radula tooth ($\times 150$).

PLATE VI

Fig. 1. Genital system in the body, diagrammatic. a. salivary gland, b. oral gland.

Fig. 2. Genital organs from above, diagrammatic ($\times 30$). a. prostatic part of vas deferens, b. rudimentary penis gland (?), c. penis, d. penis sheath, e. male orifice, f. female orifice, g. vagina, h. outer oviduct, i. spermatheca, j. albumen gland, k. hermaphrodite duct, l. mucous gland, m. ampulla.

Fig. 3. Glandular epithelium of prostata ($\times 180$), consisting of gland cells and ciliated interstitial cells.

Fig. 4. Testes with young ovaries ($\times 100$).

Fig. 5. Longitudinal section of a branchial papilla ($\times 50$). a. septum, b. liver diverticulum, c. cnidosac closed at the tip.

Fig. 6. Proximal constriction of the liver diverticulum ($\times 100$). a. septum, b. sphincter muscle ring.

Fig. 7. Tip of the branchial papilla to show the artificial opening of the cnidosac ($\times 100$). a. sphincter, b. cnidosac with a muscular coat, c. cnidopore, d. cnidocysts, e. embryonal zone of the diverticular epithelium, f. special cells.

Fig. 8. A row of cnidocysts ($\times 180$). a. nucleus of the cnidocyst, b. nucleus of the interstitial cell.

Fig. 9. A freed cnidocyst taken from mounted section ($\times 580$). Showing the vacated cytoplasm caused by a fixing fluid.

Fig. 10. A freed cnidocyst in fresh ($\times 330$). Showing colourless droplets contained in the proximal half of the cell and a cluster of nematocysts in the distal half. Discharge of some of the nematocysts in response to a mechanical stimulus.

Fig. 11. Part of the diverticular epithelium ($\times 270$). Fixed immediately after collecting from the sea. a. yellow vacuole (a thick cluster of refringent yellow granules of nearly uniform size), b. liver cells.

Fig. 12. Nerve centre from above ($\times 30$). a. cerebro-pleural ganglion, b. pedal ganglion, c. buccal ganglion, d. osphradial ganglion.

Fig. 13. Kidney from above, diagrammatic ($\times 40$). a. reno-pericardial canal, b. nephroproct, c. anus, d. main body of kidney.

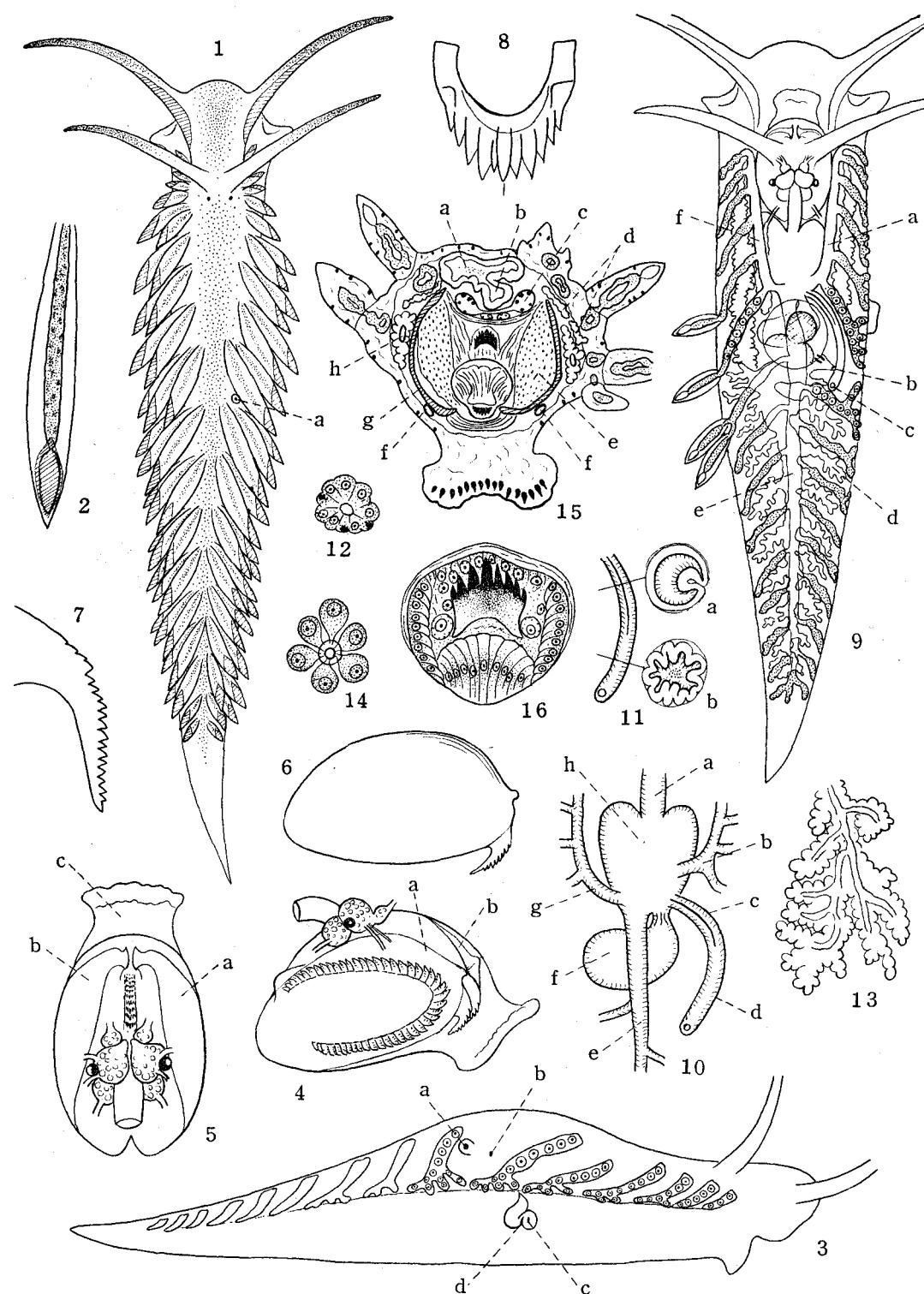
Fig. 14. Part of the branching kidney in fresh ($\times 40$).

Fig. 15. Part of the body in longitudinal section ($\times 30$). a. anus, b. nephroproct, c. pericardium, d. reno-pericardial canal, e. kidney, f. rectum.

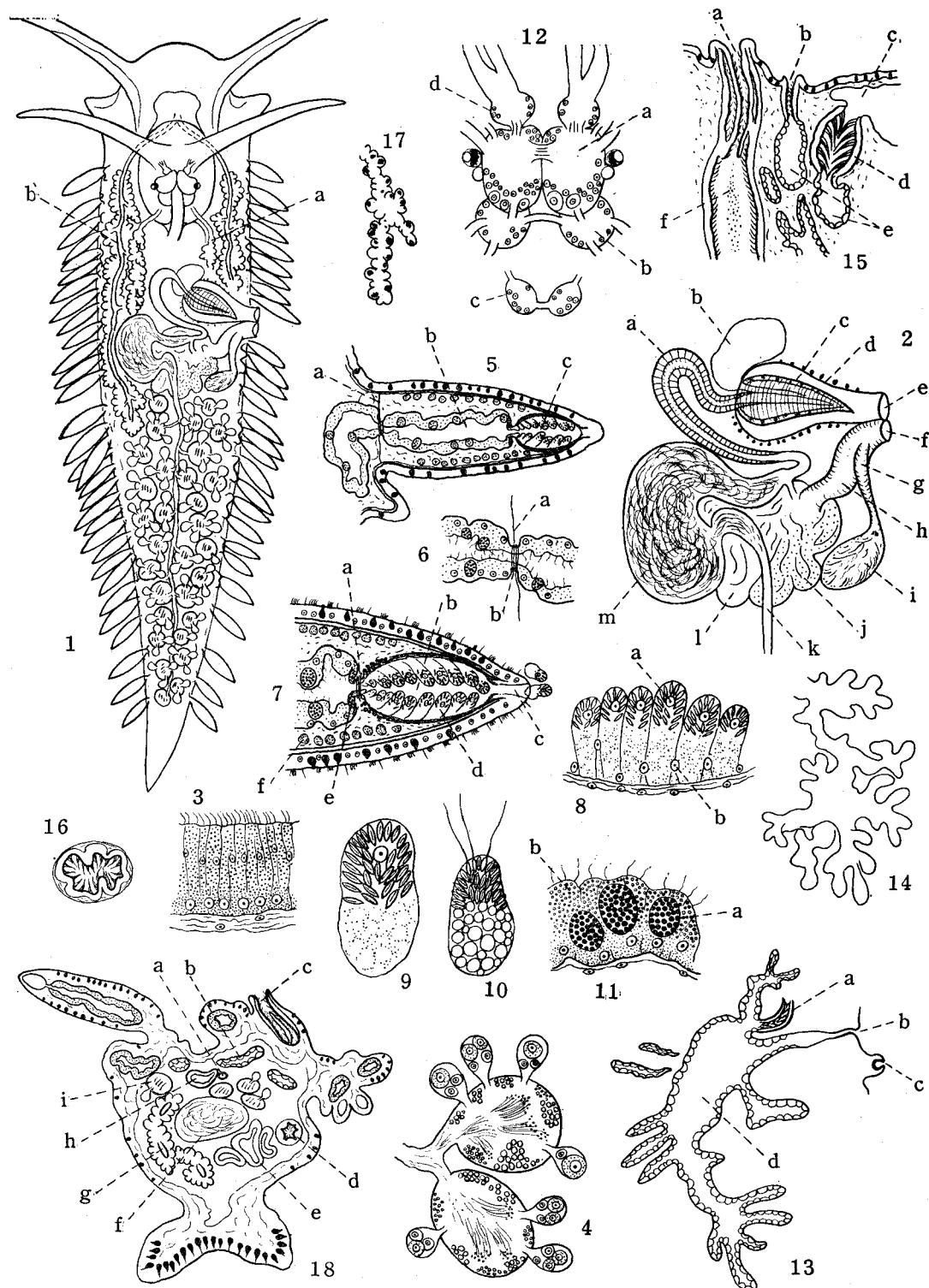
Fig. 16. Cross-section of the reno-pericardial canal ($\times 50$).

Fig. 17. Part of the salivary gland ($\times 30$).

Fig. 18. Cross-section of the body on level of the postanal liver branch ($\times 20$). a. hermaphrodite duct, b. main body of the kidney, c. anus, d. rectum, e. mucous gland of the genitalia, f. ampulla, g. oral gland, h. main canal of the left posterior liver, i. gonads.



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